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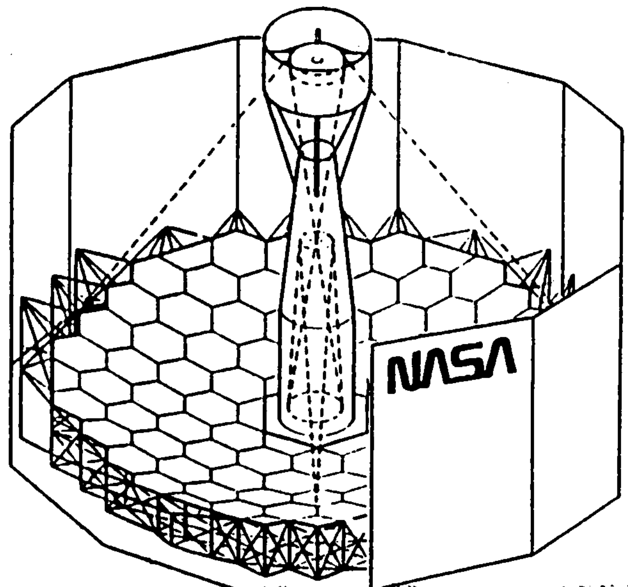
LDR STRUCTURAL EXPERIMENT DEFINITION



Richard A. Russell
Richard M. Gates

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National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665-5225

INTRODUCTION

A system study to develop the definiton of a structural flight experiment for a large precision segmented reflector on Space Station was accomplished by The Boeing Aerospace Company for NASA Langley Research Center. The objective of the study was to use the Large Deployable Reflector (LDR) baseline configuration as described in the JPL report, "A Lightweight Low Cost LDR, " as the basis for focusing an experiment definiton so that the resulting accommodation requirements and interface constraints could be used as part of the mission requirements data base for Space Station.

The ground rules for the study were (a) that the experiments would be conducted on the Space Station, (b) the test hardware would serve as a test bed for future precision segmented structures experiments, (c) the primary mirror truss is the deployable PAC truss configuration, (d) the primary mirror facets will be assembled using Telerobotics, (e) that system identification techniques will already have been developed, (f) structural characterization will be required , and (g) chopping will occur at the sensors that require it.

Results of the study defined three Space Station based experiments to demonstrate the technologies needed for an LDR type structure. The basic experiment configurations are the same as the JPL baseline except that the primary mirror truss is 10 meters in diameter instead of 20. The primary objectives of the first experiment are to construct the primary mirror support truss and to determine its structural and thermal characteristics. Addition of the optical bench, thermal shield and primary mirror segments and alignment of the optical components occur on the second experiment., The structure will then be moved to the payload pointing system for pointing, optical control, and scientific optical measurement for the third experiment.

The first experiment will deploy the primary support truss while it is attached to the instrument module structure. If possible, it will be deployed repeatedly to demonstrate reliability of kinematic deployment. After each deployment, the structural adequacy will be measured. After final deployment, the dynamic and thermal characteristics will be measured. The ability to adjust the mirror attachment points and to attach several dummy primary mirror segments with a robotic system will also be demonstrated.

Experiment two will be achieved by adding the new components and equipment to experiment one. The optical bench structure including the pre-assembled secondary, tertiary and quaternary mirrors will be attached to the instrument module. The thermal shield will then be attached after several lightweight composite mirror segments have been assembled. After installation of the optical alinement system and prototype cryogenic cooling system, the optical system will be evaluated.

Experiment three will demonstrate advanced control strategies, particuarly sensing for the alignment and control of the quaternary mirror elements, active adjustment of the primary mirror alignment and technologies associated with optical sensing. Equipment to be added for this experiment will include payload pointing system, fine pointing system, star tracker and primary mirror alinement system. This experiment will also address the feasiblity of providing an electro-mechanical quasi-static adjustment mechanisms for the primary mirror panels.

The following report is the study results which describes the experiment scenarios, configurations, descriptions, sketches, functional block diagrams and functional requirements. Also, the experiment equipment list and requirements are defined as well as the Space Station accommodation requirements and interfaces.

Large Deployable Reflector (LDR) Baseline Concept

"The Large Deployable Reflector (LDR) is a dedicated astronomical observatory to be placed in orbit above the Earth's obscuring atmosphere. It will operate in the spectral range between 30- and 1000-μm wavelength. The observatory was recommended by the National Academy of Sciences Astronomy Survey Committee (Field Committee) as one of the four major astrophysical projects of the 1980's. The NASA Office of Space Science and Applications (OSSA) has scheduled the LDR for a new start sometime in the 1990's . . .

"The present concept for the LDR telescope is a 20-meter diameter reflector. The primary mirror is a filled aperture made up of 84 hexagonal panels, each approximately 2 meters edge-to-edge. The panels are based on lightweight structural composite materials. The optical configuration is a four mirror "two stage" system. The primary mirror is passive. The active optics for figure control are at the quaternary mirror. The primary mirror panels are supported by a deployable "PAC truss" backup structure at the vertices of the hexagons.

"Four focal plane instruments covering the range of 30-1000μm are located near the vertex of the primary mirror. Some of the instruments will be cooled with stored cryogens to liquid helium temperatures.

"The spacecraft functions such as power, communications, data system, attitude control, etc., will be mounted in a Resource Module behind the primary mirror.

"The LDR will be transferred to orbit by the Space Shuttle and be assembled and tested on the Space Station. It will then be placed as a free-flyer into an orbit of >700 km."

Reference: Swanson, Paul N., A Lightweight Low Cost Large Deployable Reflector (LDR), JPL D-2283, June 1985

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Large Deployable Reflector (LDR) Baseline Concept

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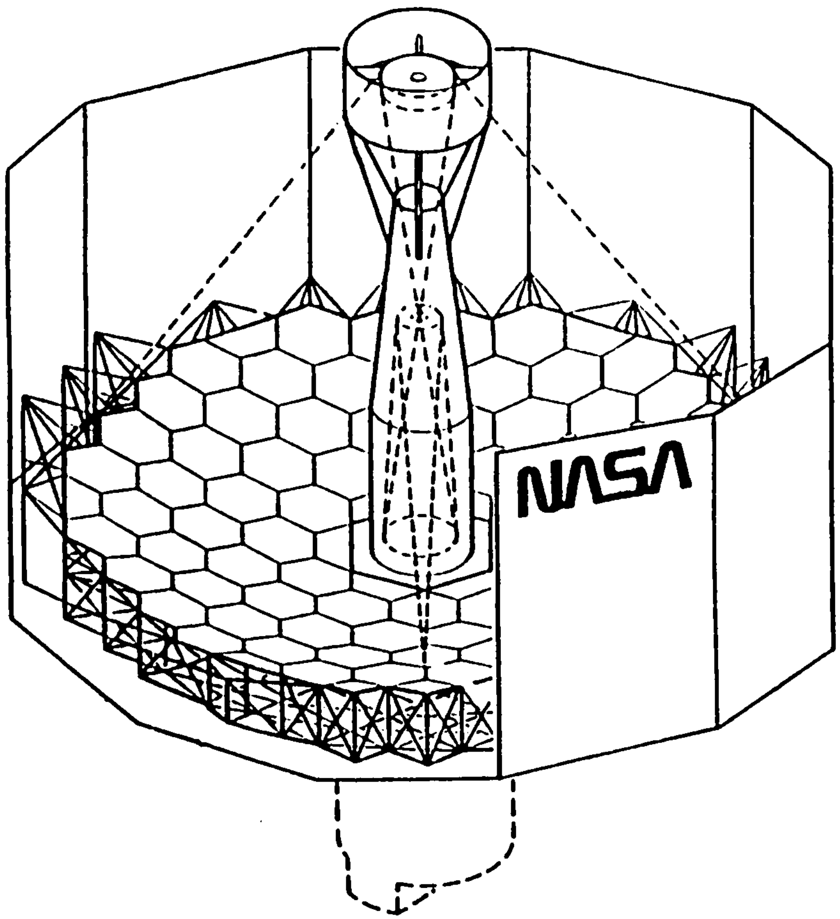

Configuration Features

- 30-1000 μm wavelength
- Light weight and low cost
- 20 meter diameter primary mirror
- Deployable G/E primary mirror truss
- Segmented primary & quaternary mirrors (84)
- Light weight composite mirrors
- Two stage optic system
- Active quaternary mirror segments
- Passive thermal control (mirrors)
- Cryogenic cooling for instruments

Reference: Paul N. Swanson, "A Lightweight Low Cost Large Deployable Reflector (LDR)", JPL D-2283, June 1985

LDR Structural Experiment Definition, Task 6 - Objectives

The first objective of this task is to use the LDR baseline configuration as described in Jet Propulsion Laboratory report JPL D-2283, "A Lightweight Low Cost Large Deployable Reflector (LDR)", June 1985, by Paul N. Swanson, as the basis for the definition of flight experiments for large precision segmented structures. The task also requires the development of experiment configurations, descriptions and sketches along with the identification of experiment requirements and equipment. Functional block diagrams will be generated to describe the experiments and their functional requirements. Finally, the accommodation requirements, interfaces and other requirements need to be quantified. These data are to be supplied in the form of completed Mission Requirements Data Base (MRDB) forms.

LDR Structural Experiment Definition
Task 6 - Objectives

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- Establish experiment scenarios for large precision segmented structures using LDR baseline as the focus

- Prepare experiment configurations, descriptions and sketches

- Identify lists of equipment and requirements for experiments

- Generate functional block diagrams and functional requirements

- Define accommodation requirements, interfaces and other requirements necessary to complete the MRDB forms

Study Ground Rules

Many of the experiment ground rules, shown on the facing page, were established at the beginning of the task, while others evolved during the course of the study. Initial ground rules included the definition of the Baseline LDR configuration, the use of telerobotics to attach the primary mirror facets (to minimize the risks associated with EVA), and the assumption that system identification techniques would already be well established for use in determining the dynamic and thermal characteristics of the experiment. All experiments defined during this task will be conducted while attached to the Space Station. It was also recognized that the demonstration of LDR technology could be accomplished using a 10 m diameter reflector instead of the 20 m diameter reflector required by LDR. To get the maximum return from the experiments, it was also agreed that it makes good sense to design the experiments for LDR technology development such that the test hardware could also be used for demonstrating and advancing post-LDR technology for precision segmented structures.

LDR Structural Experiment Definition Ground Rules

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1. Experiments will be conducted on the Space Station
2. The test hardware will serve as a testbed for future precision segmented structures experiments.
3. Baseline LDR is defined in JPL document JPL D-2283 by Paul N. Swanson, dated June, 1985.
4. The primary mirror truss is the deployable PAC truss configuration (10 meter dia.).
5. Primary mirror facets will be assembled using telerobotics (minimize EVA).
6. Assume system identification techniques are already developed.
7. Structural characterization (both thermal and dynamic) is required.
8. Chopping will occur at the sensors that require it.

LDR Technical Concerns

To determine the structures and controls technology areas that might require on-orbit flight demonstrations, a list of technical concerns was developed. These concerns, shown on the next two pages, were based upon a review of LDR documentation published over the past five years. Included in the documentation reviewed were the results from the two LDR Asilomar workshops held in June of 1982 and March of 1985, JPL report (JPL D-2283) by P. N. Swanson and JPL report (JPL D-3182) by R. Mattingly.

The test arenas that could be used to test each of the technology concerns were identified. These test arenas include 1-g ground testing facilities, flat floor suspension facilities, neutral buoyancy tanks, Shuttle sorties and Space Station facilities. The primary test arenas that are necessary to obtain the required information are shown as X's. Some ground-based tests could yield valuable, but limited, results because of the 1-g gravity field that cannot be totally eliminated. Neutral buoyancy facilities are very useful in demonstrating human involvement in a simulated zero-g environment. Their usefulness for the demonstration of LDR technology is a function of the amount of EVA (if any) that is necessary for assembling LDR.

The true test of the behavior of objects in the space environment can only be accomplished in space, either as a free-flyer or while attached to the Space Shuttle or the Space Station. Orbiter sorties impose significant limitations on testing. First, the duration of Shuttle flights is usually five to seven days, with many scheduled tasks to be accomplished. Second, the volume of the payload bay limits the size of the experiments that can be conducted. Finally, the combination of these limitations with the added complexity and cost of designing and manufacturing a deployable structural experiment that can also be re-stowed into the cargo bay after on-orbit tests makes Orbiter sorties unattractive for most large scale experiments. Orbiter based testing, however, is very valuable for testing components and subassemblies that can remain within the payload bay envelope or can be easily deployed and retracted.

Therefore, even though the Orbiter could be used to test individual or small groupings of technology concerns, the Space Station is required for the large size and long duration experiments needed for LDR. In addition, the experiment hardware could be designed to accommodate more advanced technology development tests after LDR. Thus the LDR technology experiments identified in this study are proposed as Space Station based experiments.

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LDR Structural Experiment Definition
Technical Concerns

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Concern	Test Arena: 1-G Tests	Flat Floor	Neutral Buoyancy	Shuttle Sortie	Space Station
STRUCTURAL ASSEMBLY					
Primary mirror truss					
deployment	*		O	X	X
structural rigidization	*		O	X	X
surface adjustment	X		O	X	X
Primary mirrors					
attachment	*		O	X	X
alignment	X		O	X	X
Light shield					
deployment	*		O	X	X
attachment	*		O	X	X
STRUCTURAL CHARACTERISTICS					
Static characteristics					
surface precision	*	*		X	X
effect of joints	*	*		X	X
thermal deformations	*			X	X
stiffness	X				*
Dynamic characteristics					
frequency and mode shapes	*			X	X
damping				X	X
effect of joints	X			X	X
vibration isolation	*			X	X
fluid/structure interaction	*			X	X

X - Primary test arena * - limited testing and evaluation O - applicable if EVA is required

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LDR Structural Experiment Definition
Technical Concerns (Cont'd)

BOEING

Concern	Test Arena: 1-G Tests	Flat Floor	Neutral Buoyancy	Shuttle Sortie	Space Station
CONTROLS					
Telerobotic assembly	*	*		*	X
Mirror alignment	*			X	X
Vibration control/isolation	*			X	X
Quaternary mirror control	X			X	X
Long-life CMG's	X				X
ENVIRONMENTAL EFFECTS					
Thermal	X			X	X
Atomic oxygen	*			*	X
Micrometeoroid/debris	*				*
Contamination				*	X
Outgassing	X				
ANALYSIS VERIFICATION					
Prediction of structural behavior	X			X	X
Control system analyses	X			X	X
Extrapolation of experiment to full-up LDR	X			X	X
HUMAN FACTORS/OPERATIONS					
Man-machine interface	*		O	*	X
Assembly procedures	*		O	*	X
Timeline verification	*		O	*	X
Test and checkout procedures	*			X	X
Maintenance/repair procedures	*		O	X	X

X - Primary test arena   * - limited testing and evaluation   O - applicable if EVA is required

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New Technology Requirements for LDR

The technology in several areas needs to be advanced significantly to make LDR a viable concept. Development in some of the technology areas is already in progress, either generically or specifically for LDR.

Structures and Mechanisms - One of the biggest decisions to be made is whether the primary mirror support structure will be a deployable or an assemblable truss. The ability to manufacture and operate a deployable truss structure that has joints that allow deployment, yet do not degrade the surface accuracy requirements or the dynamic characteristics of the structure needs to be demonstrated before this decision can be made. Development of the technology for lightweight composite mirrors is well under way, and must continue. Also, technology advancements in the area of mechanisms that will accommodate robotic assembly and adjustment need to be accomplished.

Construction - Robotic or telerobotic assembly has been proposed for LDR to minimize the risks involved with manual assembly using EVA. This is a major area that must be developed to demonstrate that it is a viable method for the assembly of high precision structures.

Controls - The control of the segmented quaternary mirror facets and precision pointing of the telescope are two of the keys to providing the optical precision required by LDR. Concepts for other controls-related areas (dynamic isolation, used between the telescope support module and the resource module in the baseline LDR concept, and system identification) are currently under development and need to be continued.

Instrumentation and testing - Experiment goals include the determination of the dynamic characteristics and thermal behavior of the LDR structure. Remote measurement of the structural deflections and temperatures is highly desirable because of the need to minimize the complexity and interference of instrumentation cables on a deployable or assemblable structure.

Optics - The proposed optical system (two stage optics with conjugate pairs of primary and quaternary mirror contours) is under development and is very promising. Development of wavefront sensing techniques to provide information to the quaternary mirror control system needs to continue. Also, the technology associated with optical sensing instruments, including the use of spatial chopping, needs to be advanced.

New Technology Requirements For LDR

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- Structures and Mechanisms
  - Truss structure (deployable/assemblable)
  - Optical bench structure and attachment mechanisms
  - Light-weight composite mirrors
  - Primary mirror segment attachment mechanisms
  - Primary mirror adjustment mechanism
  - Passive thermal control
- Construction
  - Robotic/telerobotic assembly
  - Thermal shield deployment and attachment
- Controls
  - Quaternary mirror control system
  - Vibration isolation system
  - Pointing control
  - System identification technique
- Instrumentation and Testing
  - Laser measurement system (static and dynamic)
  - Radiometric measurement system (thermal)
  - Dynamic excitation system
- Optics
  - Two stage optics (conjugate primary/quaternary)
  - Wavefront sensing
  - Science instrumentation
  - Immage chopping

LDR Space Station Experiments Contribute to the Overall Test Program

This chart indicates how past experience and the technology development tests in each of the test arenas identified in the previous charts contribute to the overall LDR test program. Ground tests, with simulated space environmental conditions, are the primary means for technology development. In addition to tests designed specifically for LDR, there will be Orbiter tests (COFS, Cryogenic Fluid Management Flight Experiment, etc.) and Space Station technology development (TDMX) experiments that will be conducted concurrently that will provide valuable information for LDR.

The highlighted box in the lower right-hand corner of the chart shows how the proposed LDR Space Station experiments fit into the overall test plan. The box immediately above it contains some potential Orbiter based component or subassembly tests that may be necessary to verify several technology areas prior to the Space Station experiments.

LDR Space Station Experiments Contribute to Overall Test Program

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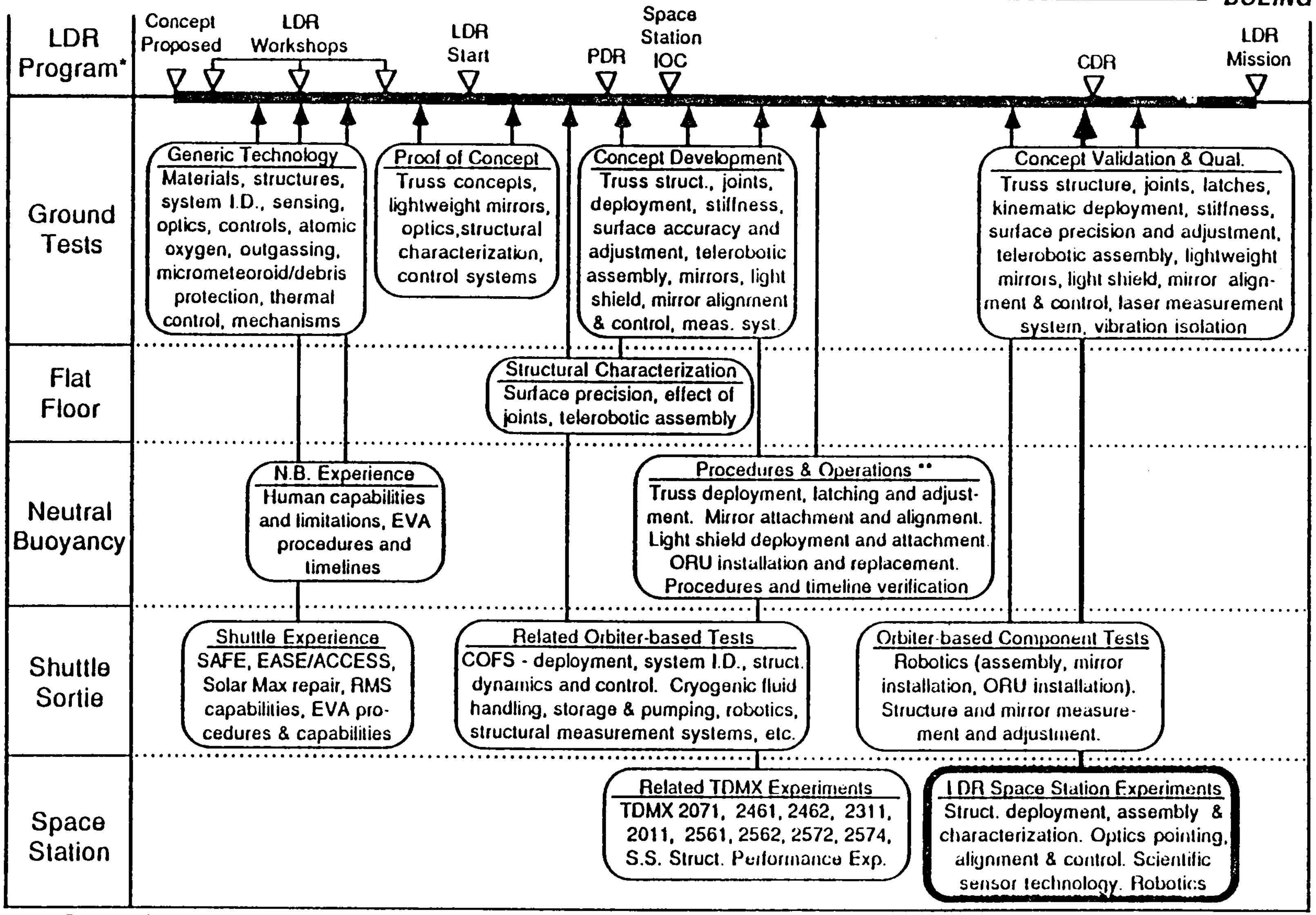

* Program timeline is not a linear scale

** Depends upon level of EVA required.

T6026

Large Precision Segmented Structures Testbed

Based on the technology concerns identified and the recommended test arenas, three Space Station based experiments are defined to demonstrate the technologies related to LDR. The overall configurations for the three experiments are shown in this figure. The basic configuration is the same as JPL's baseline LDR configuration except that the primary mirror truss is ten meters in diameter instead of twenty meters. All other dimensions and member sizes are the same.

The primary objectives of the first experiment are to construct the primary mirror support truss and to determine its structural and thermal characteristics. Addition of the optical bench, thermal shield and primary mirror segments occurs on the second experiment. An additional objective of the second experiment is to accomplish alignment of the optical components. During the third experiment, the structure is moved to the payload pointing system (PPS) (or other precision pointing system) to accomplish the goals of pointing, optical control and scientific optical measurement. Details of each experiment are presented in subsequent charts.

The experiment hardware should be designed to be used as a testbed for demonstrating future technology advancements in precision segmented structures after LDR technology demonstrations are concluded. Replaceable subsystems will allow the experimental hardware to stay abreast of the advancing technology.

SPACE STATION

Large Precision Segmented StructuresTestbed

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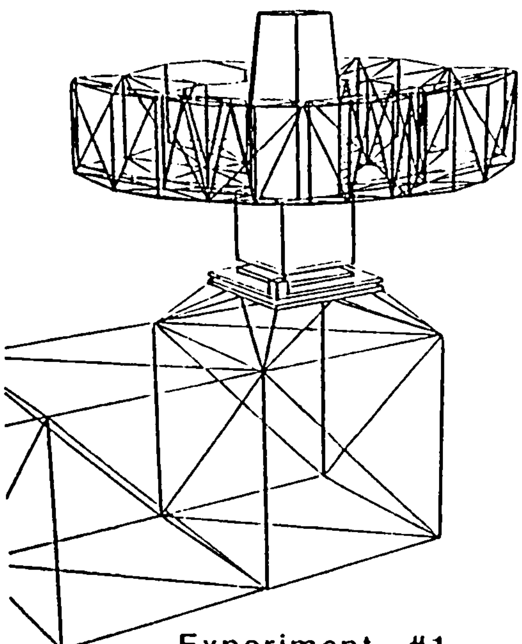
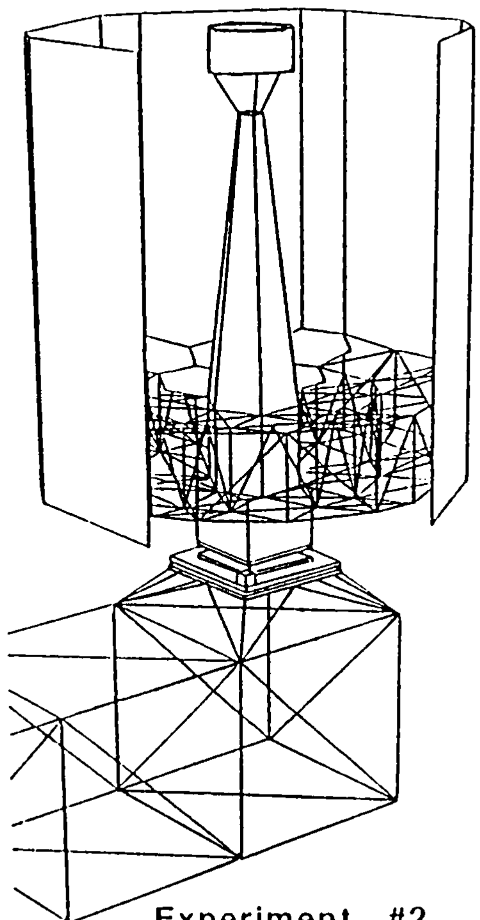
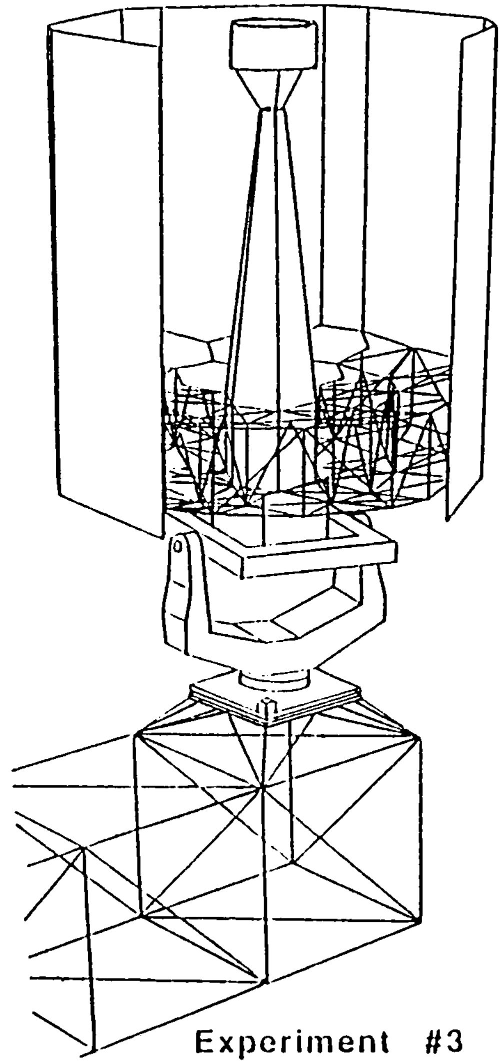


Experiment #1



Experiment #2



Experiment #3

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Flight Experiment #1

The first objective of this flight experiment is to deploy the primary mirror support truss attached to the instrument module structure. If possible, it is desirable to repeat the deployment several times to demonstrate the reliability of kinematic deployment. After each deployment, the structural accuracy of the truss surface will be measured. After the final deployment, the truss structure will also be tested to determine its dynamic characteristics and thermal response. The ability to adjust the mirror attachment points and to attach several dummy primary mirror segments with the Mobile Service Center (MSC) or other robotic system will also be demonstrated.

The experiment structure is attached to a turntable device that will facilitate the installation of mirrors and other equipment from a single position near the experiment. The other equipment listed are part of the structural characterization equipment and instrumentation.

SPACE STATION

LDR Structural Experiment Definition
Flight Experiment #1

BOEING

Location:	Space Station
Objectives:	Kinematic deployment reliability demonstration Characterization of primary mirror truss Primary mirror segment installation/adjustment
Configuration:	Primary mirror truss (10 meter diameter) Instrument module structure Support module structure Dynamic isolation system Several dummy primary mirror panels
Equipment:	Construction "turntable" Mobile Service Center (MSC) Deployment monitoring instrumentation Surface accuracy measurement system Modal excitation system System identification instrumentation Thermal measurement system

LDR Flight Experiment #1 Configuration

This figure shows the structural configuration of experiment #1. The telescope support module and instrument module structure are attached to each other on the ground with the primary mirror support truss retracted around the instrument module. The experiment hardware is attached to the Space Station truss using the universal payload attachment equipment (PAE) system designed for, and provided by, the Space Station. It includes a structural interface adapter (SIA) that is permanently attached to the Space Station truss and a payload interface adapter (PIA) attached to the payload. The interface between the PIA and the SIA is a quick latching system that permits payload attachment using the MSC. This system also includes electrical power, thermal control and data line connections for the experiment through the subsystem support module (SSM).

LDR Flight Experiment #1 Configuration

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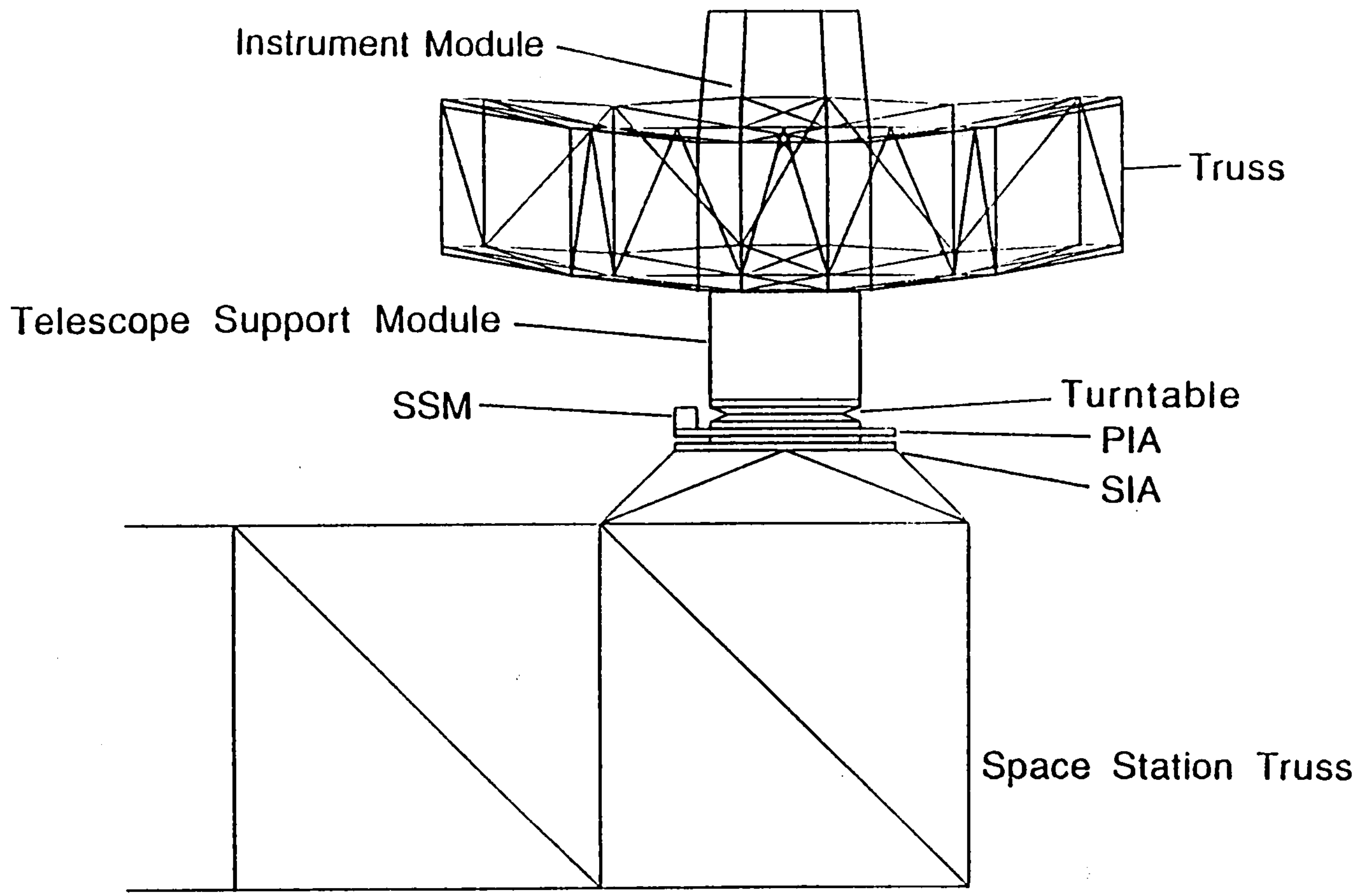

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Primary Mirror Truss Top View

A plan view of a ten meter diameter deployable hybrid PAC truss concept proposed by R. Bamford of JPL and J. M. Hedgepeth, consultant, is shown in this figure. This concept is a PAC truss configuration modified to allow the truss to remain continuous as it is folded around the instrument module structure. The triangular truss sections are double fold trusses (with hinges at both ends of all members and knee joints at the centers of all "circumferential" members) while the radial bays (rectangular sections) are single fold trusses (with hinged joints at the intersection of the rectangles). Vertical members connecting the upper and lower surfaces of the truss are continuous members while the diagonal members running between the upper and lower surfaces either hinge or telescope. More details of the deployment are shown in the next figure.

The primary mirror surface is made up of hexagonal facets, two meters in size, as shown in the figure. Three different mirror facet contours are required to produce the parabolic surface of this ten meter diameter reflector. Each is attached to the truss at three points. The mirror on the right is attached at three equally spaced apexes of the hexagon. The mirrors that attach to the radial bays, however, are attached to the truss at two adjacent apexes and a third point at the center of the opposite side.

Primary Mirror Truss Top View

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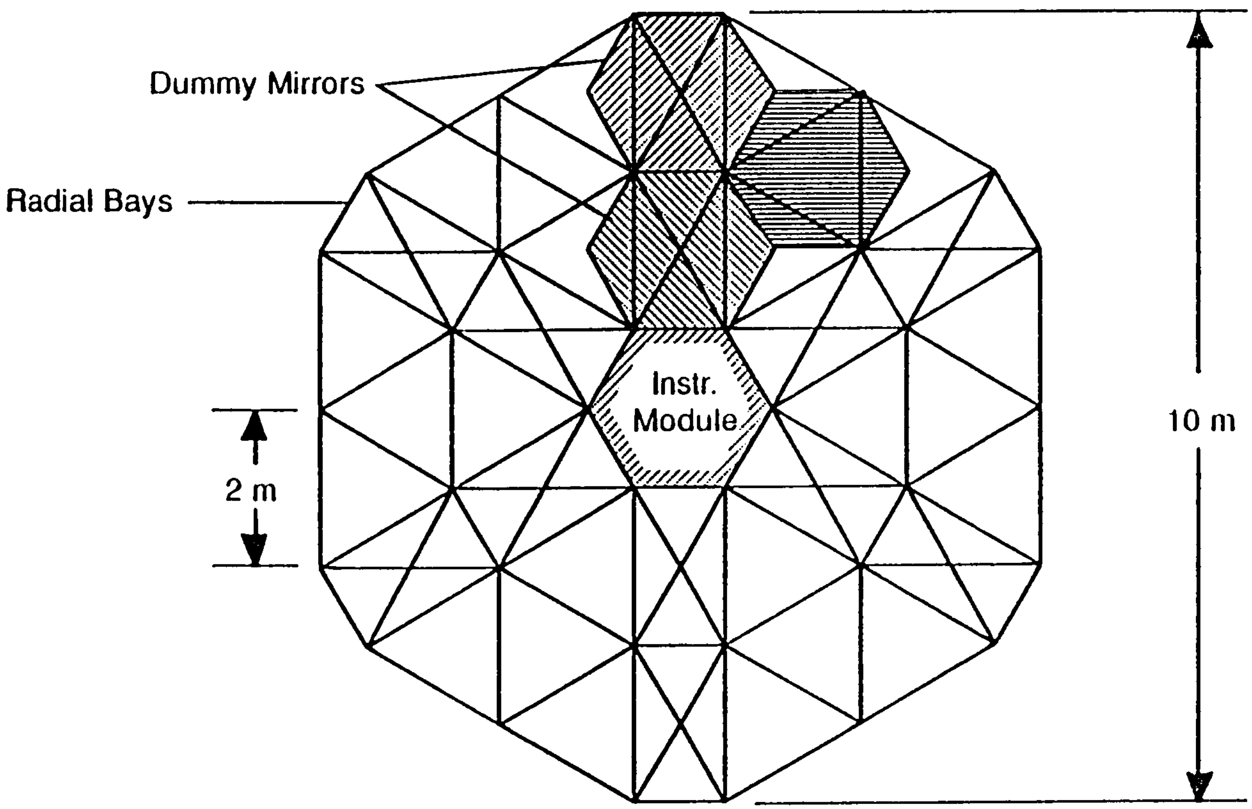
Deployable Hybrid PAC Truss*



* Concept courtesy of R. Bamford of JPL & J. M. Hedgepeth, consultant

Primary Mirror Truss Deployment Geometry

This figure shows the geometry of the truss deployment looking at a section through a pair of radial bays. The diagonal braces are shown to be hinged in this figure. They could be designed to be telescoping members if they were connected to the opposite corners of their respective parallelograms.

When packaged, the truss is latched to the instrument module structure. The truss deploys uniformly and is highly synchronized because of the geometry of the PAC truss concept.

Primary Mirror Truss Deployment Geometry

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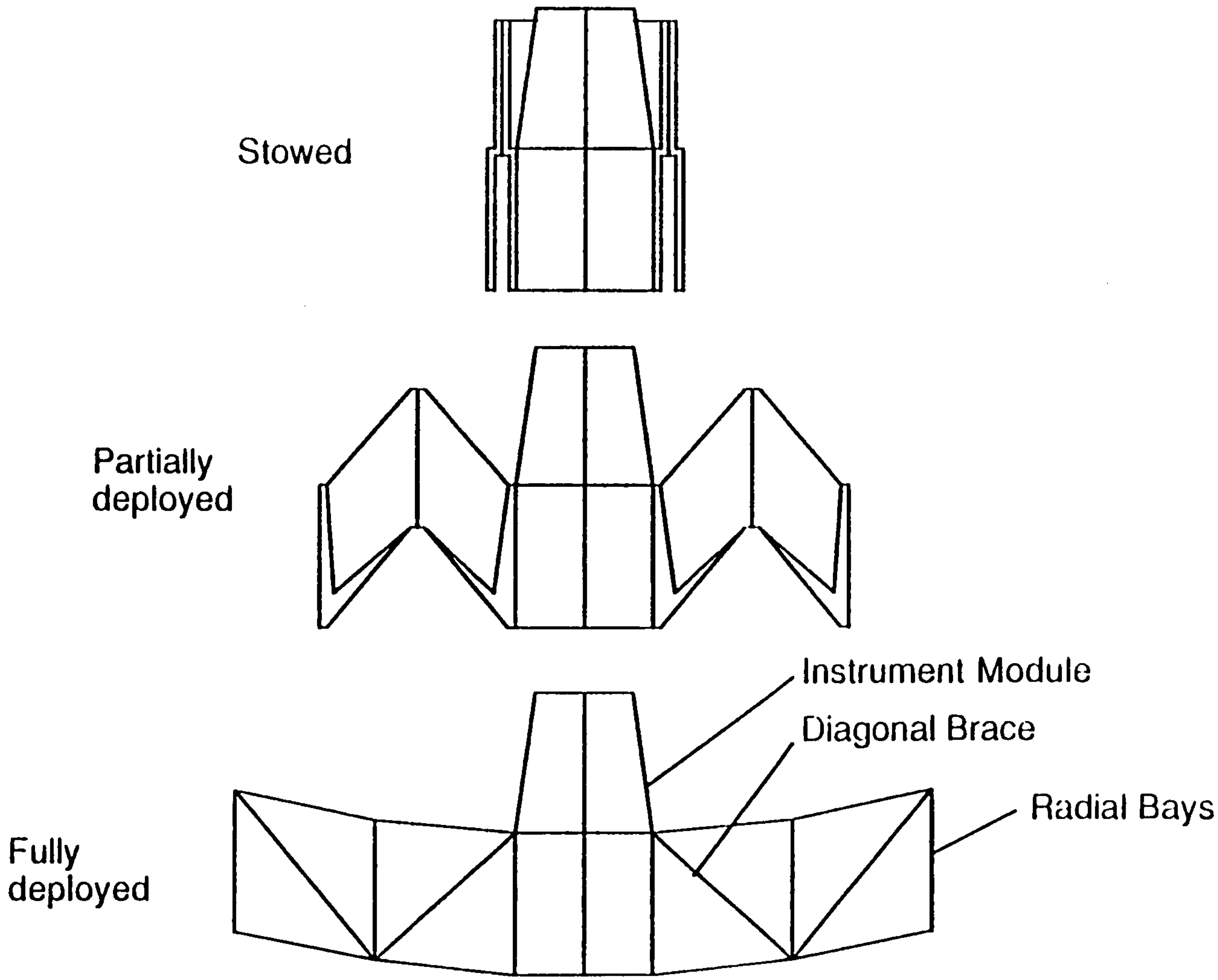
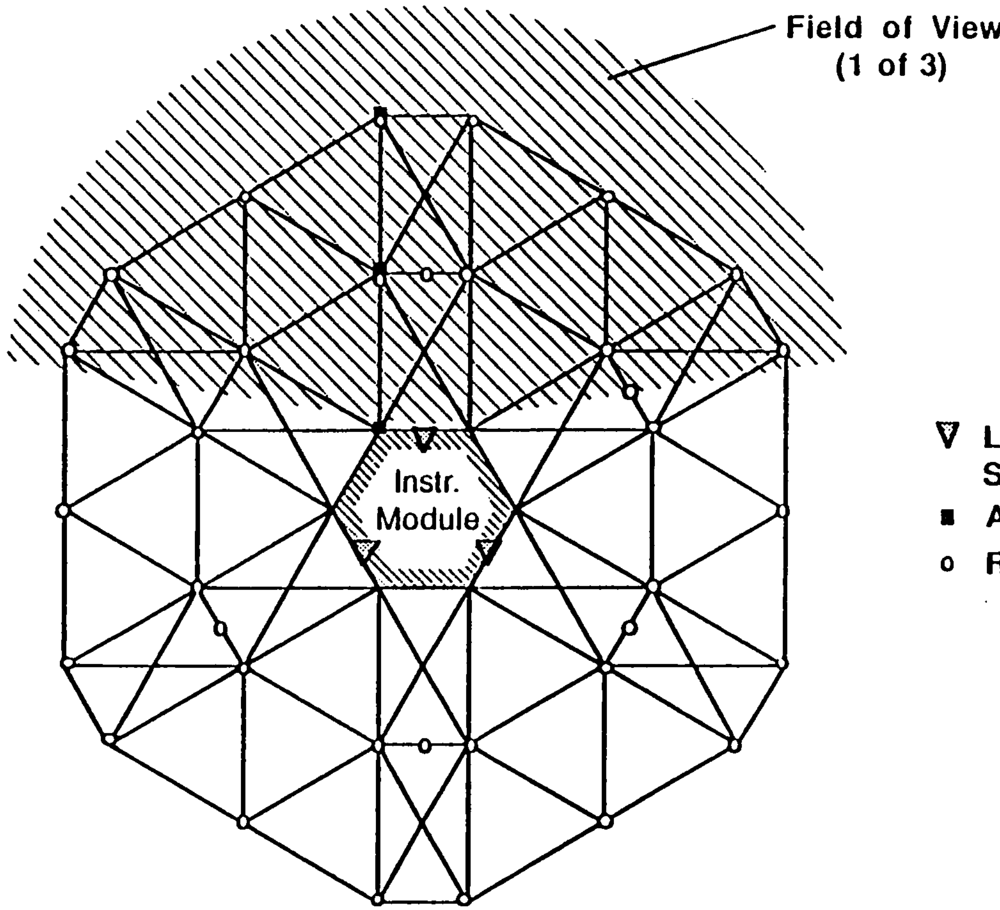


T6018

Primary Reflector Measurement System - Static and Dynamic

The location of all mirror attachment points on the support truss will be measured using three laser measurement systems located at the top of the instrument module structure as shown in the figure. Their fields of view are overlapping to provide redundancy and calibration data. They will be used to measure the initial position of the deployed structure, the thermal deformations as the Space Station moves into and out of the Earth's shadow, the response of the truss to dynamic excitation, and the accuracy of the truss surface following significant dynamic events. Accelerometers located at several truss locations will be used to complement the laser measurements. The accelerometers are located on the radial bays to permit the routing of instrumentation cables. Since the radial bays are single fold trusses, the interior spaces can be used for cable routing without sacrificing packaging volume.

Primary Reflector Measurement System
Static and Dynamic



- ▽ Laser Measurement Systems (3)
- ■ Accelerometers (3 triax.)
- o Retroreflectors (36)

Primary Reflector Surface Measurement System

Each of the three surface measurement systems contains a laser source and two sensing units: one for range detection and one for angular position sensing. Thus, a three-dimensional location of each reflector can be determined with resolution capability in the micron range. The Spatial, High-Accuracy, Position-Encoding Sensor (SHAPES) under development at JPL is a candidate for this experiment.

Primary Reflector Surface Measurement System

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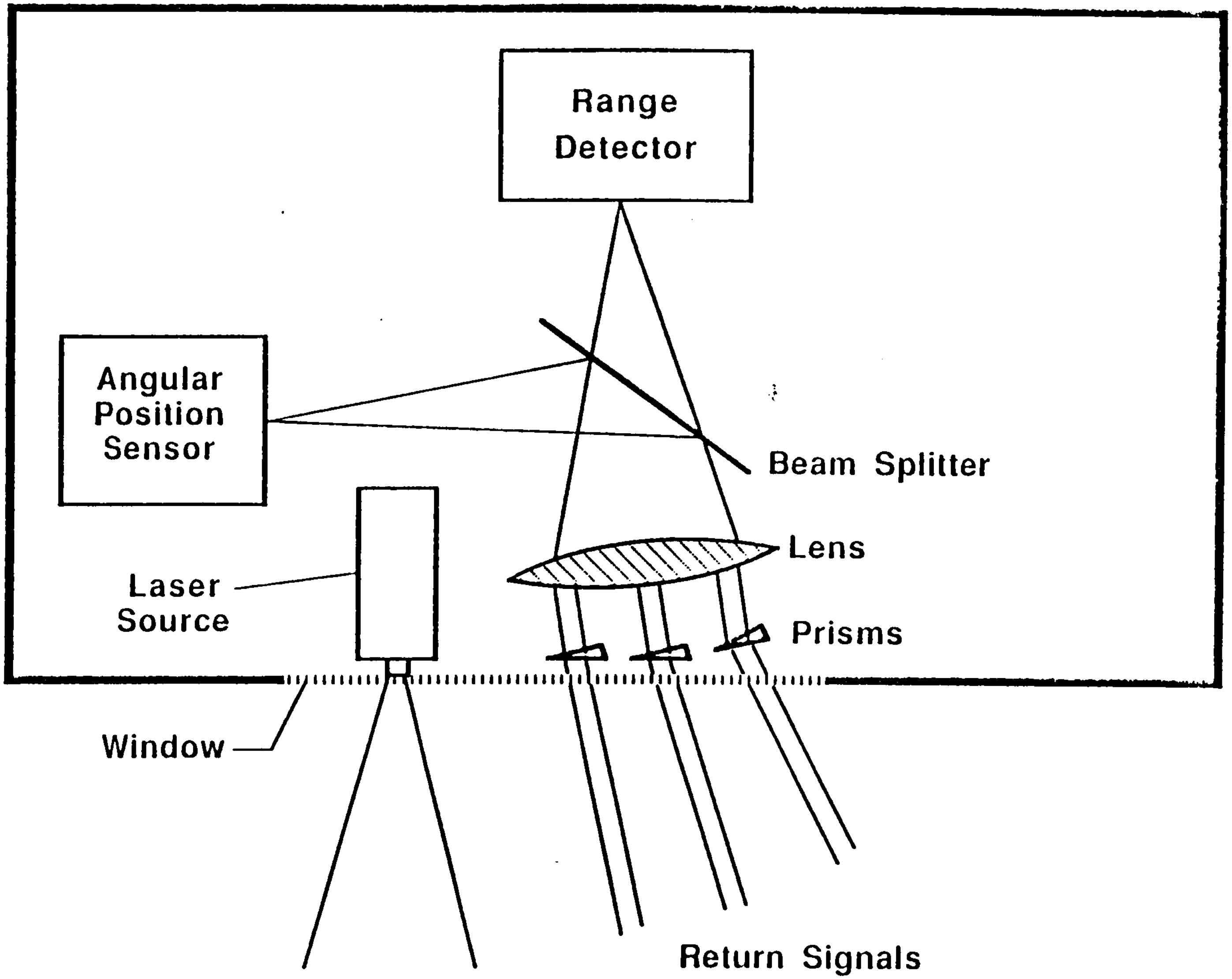

T6014

Primary Reflector Measurement System - Thermal

The distribution of structural temperatures is measured using three radiometric cameras also mounted on the instrument module structure. Their fields of view (one of which is shown in the figure) overlap to provide redundancy and calibration information. These cameras, currently under development, map the relative infrared radiation distribution of objects in their field of view. Several thermocouples are mounted to the truss structure to provide absolute temperatures to calibrate the camera system.

Primary Reflector Measurement System
Thermal

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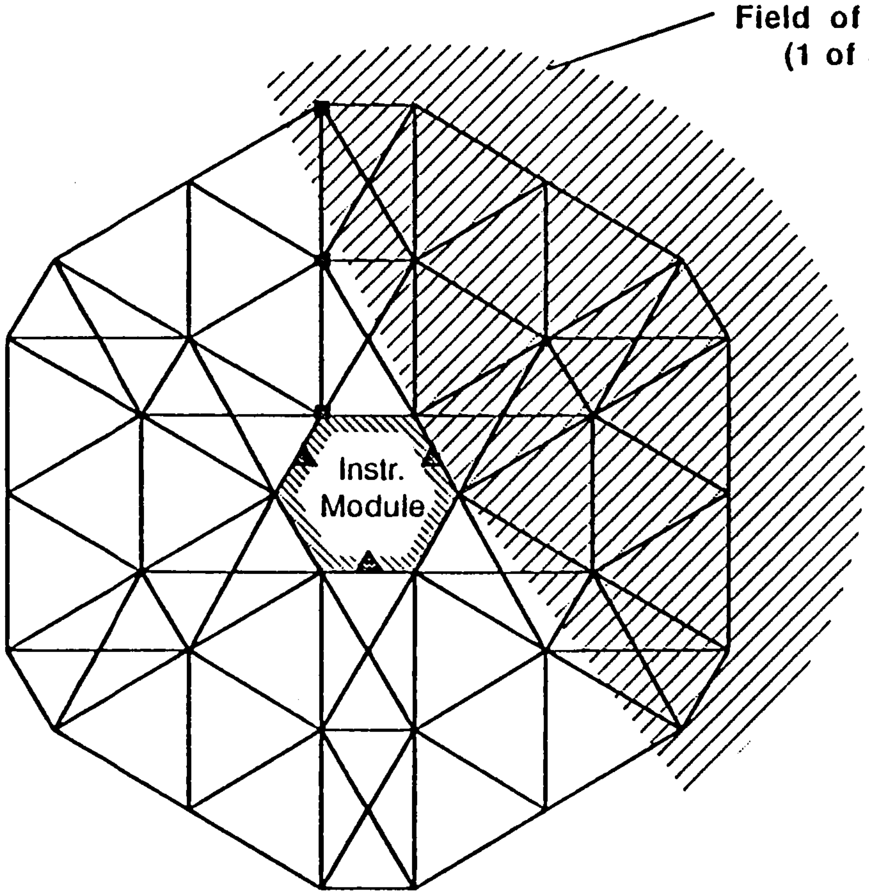

▲ Radiometric Measurement Systems (3)

■ Thermocouples (3)

T6024

LDR Flight Experiment #1 Functional Flow

After the test hardware arrives at the Space Station, it is removed from the STS and attached to the construction turntable. Following experiment preparation, experiments are performed to demonstrate the kinematic deployment of the primary mirror support truss. Two optional paths are shown to allow for the possibility (and desirability) of repeating the deployment and accuracy measurement to verify repeatability and reliability of the deployment. If the cost of producing a retractable truss is prohibitive, the truss will be deployed just once. After the final deployment and accuracy measurement, the mirror attachment points will be adjusted, if necessary, to predetermined accuracy. Thermal deformations of the truss surface will then be measured as the Space Station traverses through the Earth's shadow. Next the dynamic characteristics of the test hardware will be determined by exciting the structure and measuring its response with the system identification instrumentation. Accuracy measurements will be performed again to determine whether the dynamic tests influenced the surface accuracy. If necessary, the mirror attachment points will be readjusted. The Space Station Mobile Service Center (MSC) will then be used to demonstrate the attachment of several dummy mirror panels to the truss. The effect of these mirror panels on the dynamic characteristics of the experiment will then be determined, followed by structural accuracy measurements.

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LDR Flight Experiment #1 Functional Flow

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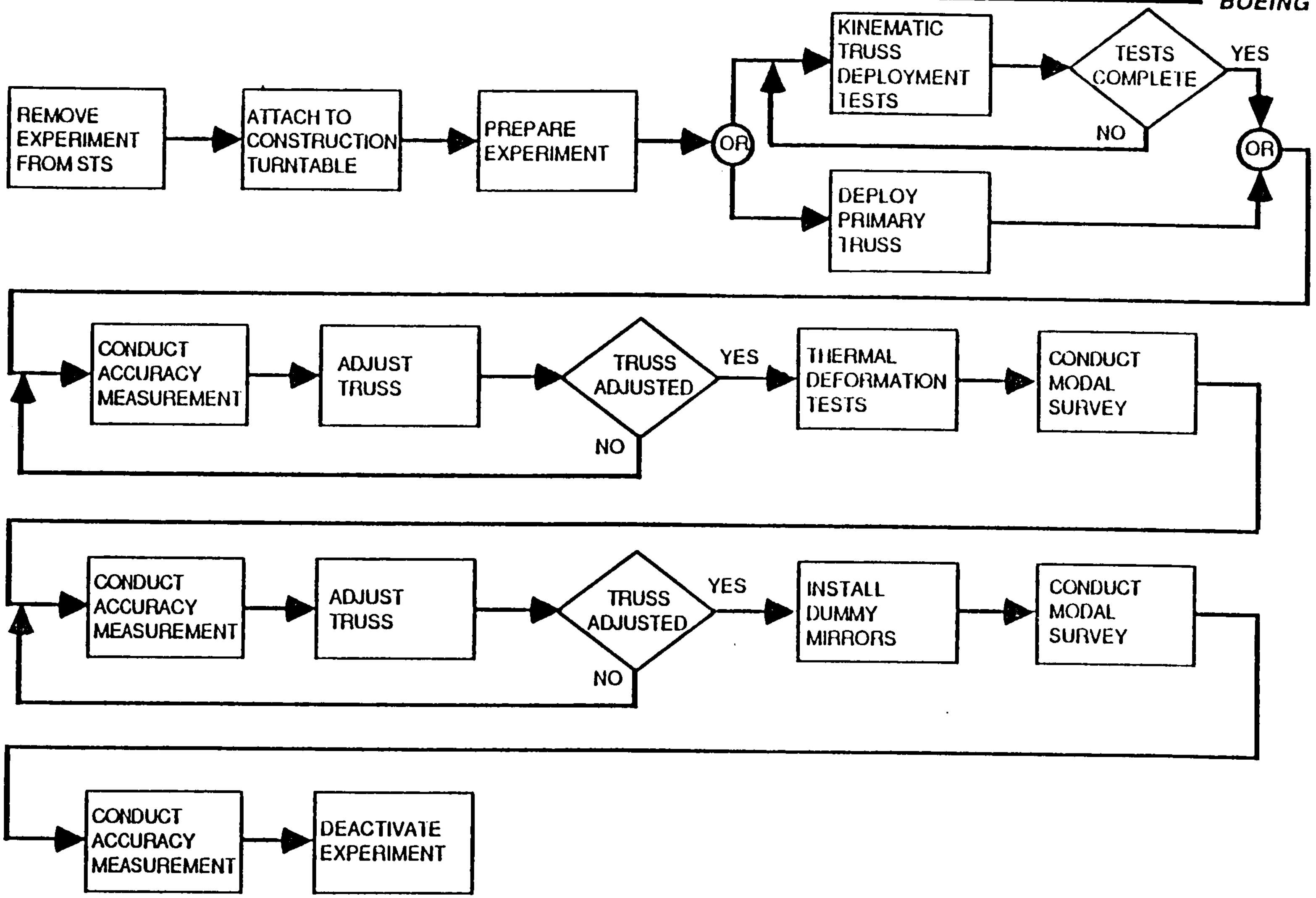

T6008

Flight Experiment #2

The objectives of the second experiment are to continue to characterize the LDR structure, to demonstrate the installation of actual light weight composite mirror panels and the thermal shield, to align and control the optics using the active quaternary mirror segments, and to demonstrate thermal control, mirror adjustment, and optical sensing.

The structural configuration for this experiment is achieved by adding the new components and equipment (shown within the dotted lines to) the structure used for experiment #1. The optical bench structure including the pre-assembled secondary, tertiary and quaternary mirrors is attached to the instrument module structure. The thermal shield is attached and several light weight composite mirror segments are attached. Depending upon the results of the installation of dummy mirror panels during experiment #1, a dedicated, high accuracy robotic assembler may be required to install the mirrors (after it is verified using the dummy mirror panels provided by experiment #1). The optical alignment sensing system and quaternary mirror control system are added along with prototype optical sensing instrumentation. Cooling of the optical instruments is accomplished by a prototype of the cryogenic cooling system.

LDR Structural Experiment Definition
Flight Experiment #2

BOEING

Location: Space Station

Objectives:
- Structural characterization
- Light-weight composite mirror installation
- Thermal shield installation
- Optical alignment and control
- Thermal control
- Sensing technology

Configuration:
- Primary mirror truss (10 meter diameter)
- Instrument module structure
- Support module structure
- Vibration isolation system
- Optical bench structure & mirrors
- Thermal shield
- A number of primary mirror segments (light-weight composite)

Equipment:
- Construction "turntable"
- Surface accuracy measurement system
- Modal excitation system
- System identification instrumentation
- Thermal measurement system
- Telerobotic system prototype
- Optical alignment sensing and control system
- Prototype of sensing instruments
- Cryogenic cooling system prototype

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LDR Flight Experiment #2 Configuration

The major configuration changes introduced by experiment #2 are shown in this figure. They are the addition of the optical bench (including the secondary, tertiary and quaternary mirrors), the attachment of several lightweight mirror panels, and the attachment of the thermal shield. Other equipment, identified in the previous figure, are installed within the instrument module and the telescope support module.

LDR Flight Experiment #2 Configuration

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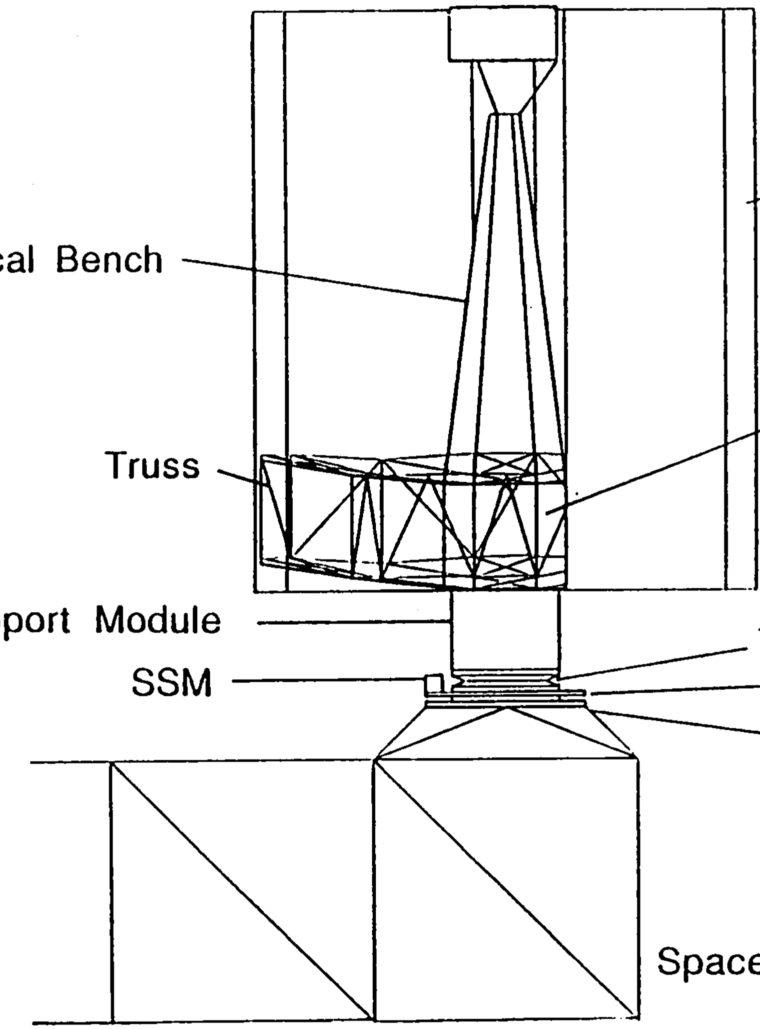

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LDR Flight Experiment #2 Functional Flow

After unloading the new equipment from the STS and preparing the experiment, the first task is to measure the structural accuracy of the truss structure and to conduct a modal survey. This is done to determine what changes, if any, have occurred in the time between the conclusion of experiment #1 and start of experiment #2. Depending upon the scheduling of the two experiments, many months may pass during which the structure is exposed to the space environment.

Several light weight mirror panels are then installed, followed by accuracy measurements and a modal survey.

The deployment or installation of the thermal shield is demonstrated next. This is followed by accuracy measurements to determine the effect the thermal shield on thermal deformations and a modal survey to determine the effect of the thermal shield on the dynamic characteristics of the experiment.

Demonstration of the primary mirror measurement system is performed next, with robotic adjustment of the mirror facets, if necessary.

Quaternary mirror experiments are conducted next to demonstrate the quaternary mirror alignment and control system. A bogus target (IR source) will be required for this task.

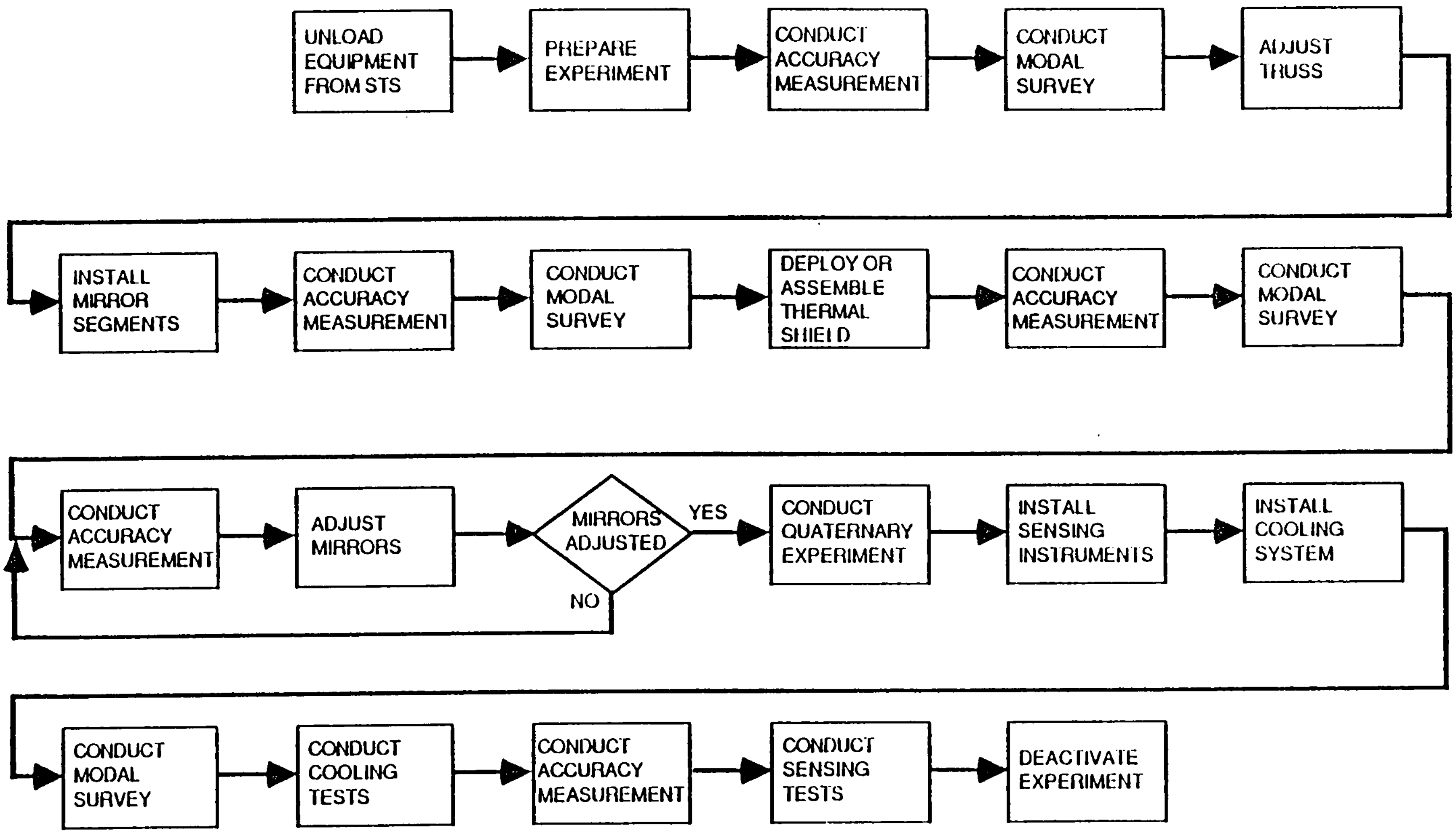
The installation of the prototype sensing instruments and the prototype cryogenic cooling system are the next two tasks, followed by a modal survey to characterize the structure including these new pieces of equipment.

Tests of the cryogenic cooling system and its effect on optical accuracy are followed by tests of the prototype scientific sensing instrumentation.

SPACE STATION

LDR Flight Experiment #2 Functional Flow

BOEING



16009

Flight Experiment #3

The objectives of experiment #3 are to perform experiments to demonstrate advanced control strategies, particularly wavefront sensing for the alignment and control of the quaternary mirror elements, active (quasi-static) adjustment of primary mirror alignment, and technologies associated with optical sensing.

The equipment added to experiment #2 for experiment #3 is shown within the dotted lines in this figure. The LDR pointing requirements are more precise than the capability of the proposed Space Station Payload Pointing System (PPS). Therefore a fine pointing system may be required for this experiment. A star tracker will be added to provide pointing information. This experiment will also explore the feasibility of providing electro-mechanical quasi-static adjustment mechanisms for the primary mirror panels.

LDR Structural Experiment Definition
Flight Experiment #3

BOEING

Location:	Space Station
Objectives:	Advanced control strategy development - Wavefront error sensing - Quasi-static primary mirror alignment - Sensing technology
Configuration:	Primary mirror truss (10 meter diameter) Instrument module and support module structure Optical bench structure and mirrors Thermal shield A number of primary mirror segments Vibration isolation system
Equipment:	Surface accuracy measurement system Modal excitation system System identification instrumentation Thermal measurement system Optical alignment sensing and control system Prototype of sensing instruments Cryogenic cooling system prototype Payload Pointing System (PPS) Fine pointing system (if required) Star tracker Primary mirror alignment system

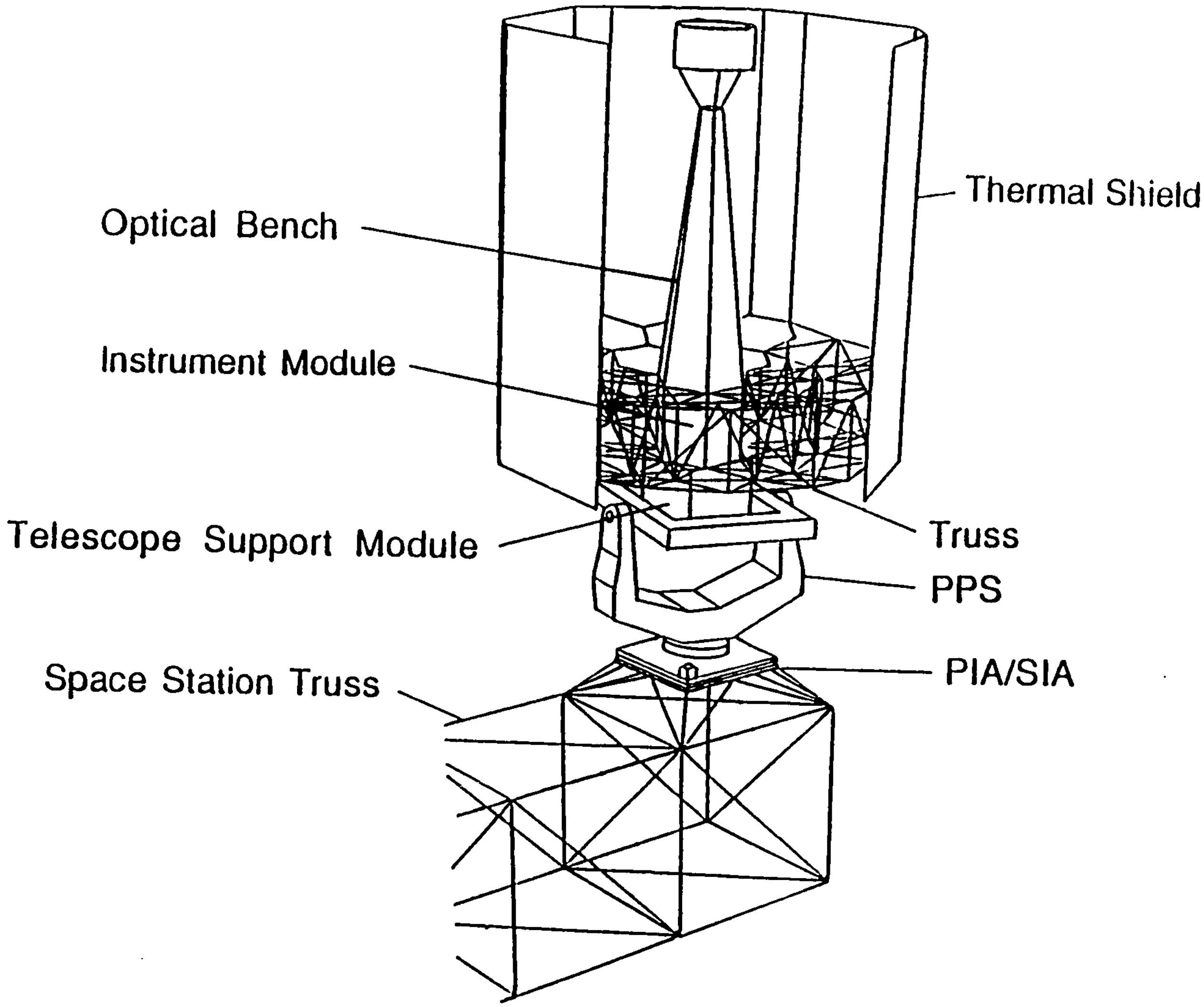
T6007

LDR Flight Experiment #3 Configuration

This figure shows the LDR flight experiment mounted on the Space Station Payload Pointing System (PPS). The PPS is a coarse pointing system that provides the capability to point payloads at selected targets and compensates for Space Station motion. It has a hemispherical field of view with a pointing accuracy of 1 arc minute, pointing stability of 30 arc sec/1800 sec, and pointing jitter of 15 arc sec/sec. To achieve LDR pointing accuracy requirements (0.1 arc sec), a fine pointing system is required.

LDR Flight Experiment #3
Configuration

BOEING

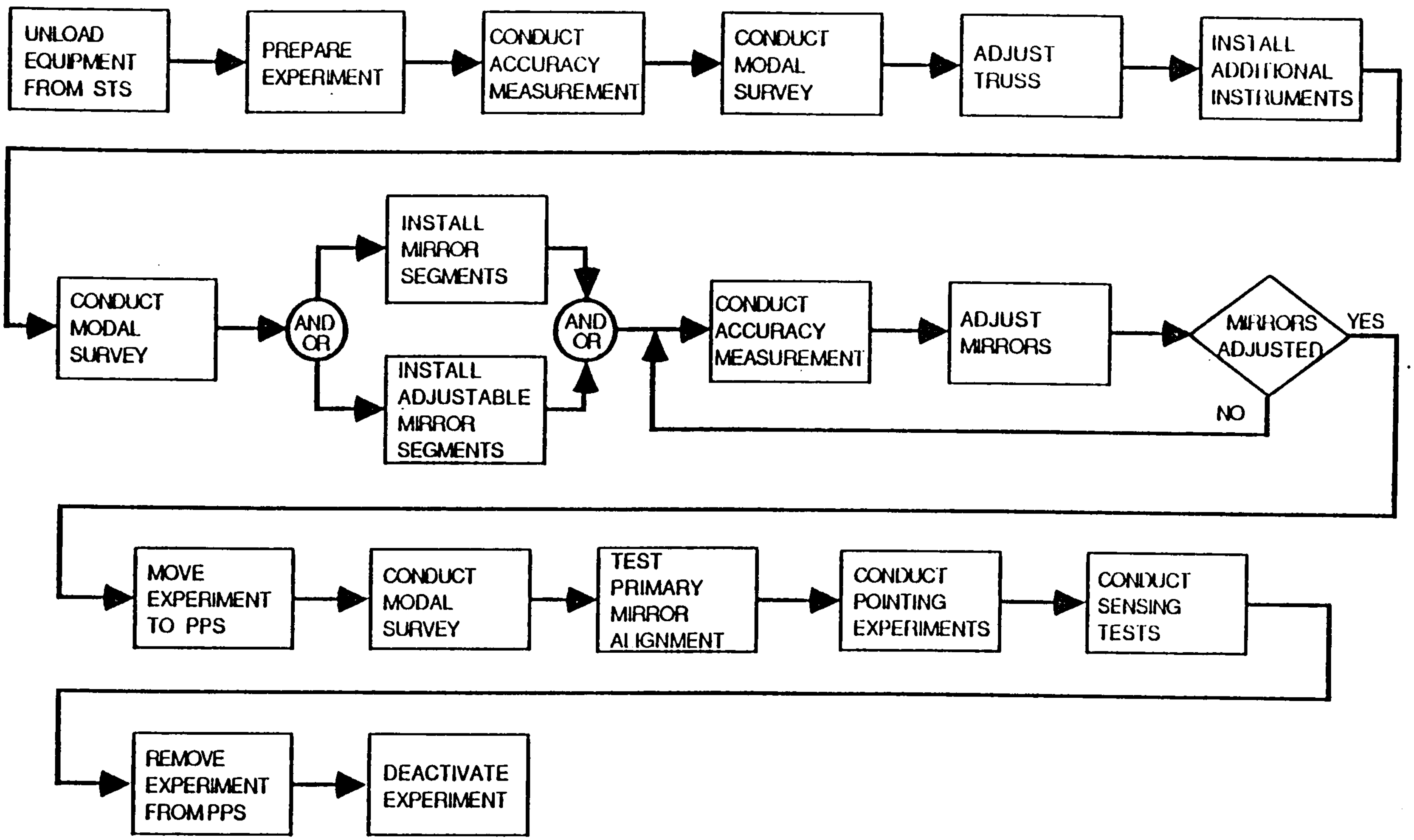


LDR Flight Experiment #3 Functional Flow

This figure shows the functional flow for experiment #3. Accuracy measurements and a modal survey are conducted at the beginning to determine any changes that may have occurred since the conclusion of experiment #2. Adjustments are made if necessary. The new instruments are installed and a modal survey is conducted to quantify the dynamic characteristics of the modified configuration. The next task is to install additional primary mirror panels. The functional flow shows two options here: the installation of mirror panels similar to those installed on the previous experiment or the installation of panels that have the ability to be remotely adjusted using electro-mechanical devices. The alignment of all the mirrors is checked and adjustd as required. The experiment is then moved to the PPS and a modal survey is condcted to determine the dynamic characteristics of the complete system. Mirror aligment is again measured and adjustments are made as required. Telescope pointing expriments and optical sensing experiments are then conducted. Following these experients, the experiment hardware is removed from the PPS and returned to the Space Staion PAE.

LDR Flight Experiment #3
Functional Flow

BOEING



Experiment Mass Properties

The mass of major equipment items contained in the optical system, instrument module and telescope support module are itemized in this table. The documents listed below were used as the primary source of mass data. The quantities of each equipment item needed for each of the three experiments are shown. For experiments two and three, the incremental quantities that are added to the previous experiment are shown as well as the total number accumulated. Additional mass for the third experiment may be required to replenish cryogens.

References:

1) Swanson, Paul N., A Lightweight Low Cost Large Deployable Reflector (LDR), JPL D-2283, June 1985

2) Mattingly, Richard, Space Station Staging of the Large Deployable Reflector (LDR), Interim Requirements Report, JPL D-3182, January 1986

LDR STRUCTURAL EXPERIMENT DEFINITION

EXPERIMENT MASS PROPERTIES

EQUIPMENT	MASS (KG)	QUANTITIES				
		EXP. #1 TOTAL	INCR. FOR #2	EXP. #2 TOTAL	INCR. FOR #3	EXP. #3 TOTAL
OPTICAL SYSTEM						
PRIMARY MIRROR PANELS	38	3	3	6	2	8
PRIMARY SUPPORT TRUSS	400	1		1		1
THERMAL SHIELD	350		1	1		1
OPTICAL BENCH STR. & MIRRORS	600	0.7	0.3	1		1
QUAT. MIRROR ACTUATORS	150		1	1		1
CABLING	136	0.5	0.5	1		1
OPTICAL FINE GUIDANCE SENS.	150		1	1		1
WAVEFRONT SENSORS	80		1	1		1
		---	---	---	---	---
Subtotals		1002	1092	2094	76	2170
INSTRUMENT MODULE						
INSTRUMENTS (COLD SECTIONS)	92		1	1	3	4
STRUCTURE	750	1		1		1
CABLING	17	1		1		1
THERMAL CONTROL	105		1	1		1
COLD COOLER STAGES	50		1	1		1
CRYOGEN STORAGE	2080	1		1		1
CRYOGEN	400	0	1	1	*	1
		---	---	---	---	---
Subtotals		2847	647	3494	276	3770
TELESCOPE SUPPORT MODULE						
INSTRUMENT SUPPORT ELECT.	50	1		1	3	4
STRUCTURE	275	1		1		1
CABLING	25	1		1		1
THERMAL CONTROL	37		1	1		1
WARM COOLER COMPONENTS	150		1	1		1
REFLECTOR SUPPORT ELECT.	100	1		1		1
WARM INSTRUMENT COMPONENTS	370		1	1		1
		---	---	---	---	---
Subtotals		450	557	1007	150	1157
TURNTABLE ASSEMBLY FIXTURE	600	1		1		1
		---	---	---	---	---
Subtotals		600	0	600	0	600
totals (KG)		4899	2296	7195	502	7697

* replenishment of consumables may be required

Equipment Power Requirements

Electrical power usage for each of the equipment items is shown in this table. The quantities of each used to calculate the operational and peak power loads is shown for each of the three experiments. The equipment items that are not included in the calculation of these power levels do not operate at the same time, and are not significant to the calculation of operational or peak power levels. The totals shown are cumulative values as more equipment is added with each experiment. The power required by the Mobile Service Center (MSC), robotic assembler and Payload Pointing System (PPS) are not included in this table. These requirements are based on the two JPL reports identified on the previous chart.

LDR STRUCTURAL EXPERIMENT DEFINITION

EQUIPMENT POWER REQUIREMENTS

EQUIPMENT	POWER (W)	QUANTITIES* EXP. #1 OPER	EXP. #1 PK.	EXP. #2 OPER	EXP. #2 PK.	EXP. #3 OPER	EXP. #3 PK.
TURNTABLE	100						
DEPLOYMENT SYSTEM	100						
DEPLOYMENT SENSOR	0.4						
LASER MEASUREMENT SYSTEM	176	3	3		3		3
MODAL EXCITATION SYSTEM	100	1	1				
ACCELEROMETERS	0.4	9	9	9	9		9
THERMAL MEASUREMENT SYSTEM	150		3	3	3	3	3
OPTICAL ALIGNMENT SENS. & C/S	300			1	1	1	1
SCIENCE INSTRUMENT	225			1	1	4	4
CRYOGENIC COOLING SYST.	1450			1	1	1	1
STAR TRACKER	100					2	2
PRIMARY MIRROR ALIGNMENT SYST.	100						
totals (KW)		0.6	1.1	2.4	3.0	3.3	3.8

* Only those equipment items that could be operating simultaneously are quantified to determine operational power requirements.

Note: MSC & PPS power reqirements are not included.

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15. Supplementary Notes

Richard A. Russell, Langley Research Center, Hampton, Virginia
Richard M. Gates, The Boeing Aerospace Company, Seattle, Washington

16. Abstract

A study was performed to develop the definition of a structural flight experiment for a large precision segmented reflector that would utilize the Space Station. The objective of the study was to use the LDR baseline configuration as described in the JPL report, "A Lightweight Low Cost LDR," for focusing on experiment definition activity which would identify the Space Station accommodation requirements and interface constraints.

Results of the study defined three Space Station based experiments to demonstrate the technologies needed for an LDR type structure. The basic experiment configurations are the same as the JPL baseline except that the primary mirror truss is 10 meters in diameter instead of 20. The primary objectives of the first experiment are to construct the primary mirror support truss and to determine its structural and thermal characteristics. Addition of the optical bench, thermal shield and primary mirror segments and alignment of the optical components occcur on the second experiment. The structure will then be moved to the payload pointing system for pointing, optical control and scientific optical measurement for the third experiment.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
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